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Some features of the decay of Au^{196} to Pt^{196}

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With 2 figures in the text

ABSTRACT

The conversion and gamma-ray spectra have been investigated with high energy resolution. The third excited state at 1091.3 ± 0.3 keV has been assigned spin parity $1-$, and the total disintegration energy has been estimated to 1110^{+24}_{-11} keV.

Introduction

The ground state of Au^{196} decays with a half-life of 5.6 days by a beta branch leading to the 426 keV level in Hg^{196} and electron capture taking place to excited levels in Pt^{196}. The decay scheme adopted by the Nuclear Data Group [1] shows in Pt^{196} the two lowest states having spin-parity $2+$ (Fig. 2). These may, according to Scharff-Goldhaber and Weneser [2], be regarded as one- and two-phonon states of quadrupole oscillation. The higher level should be degenerate with the characters $0+$, $2+$ and $4+$. A crossover transition, being a two-phonon jump should be forbidden. Alburger [3], looking for the crossover, found that the K-conversion line intensity ratio of the crossover to the cascade was less than 1/12 000. Thus the ratio for the matrix elements of the corresponding transitions was found to be less than 10^{-5}, while for the neighbouring Pt^{192} and Pt^{194} he quoted a ratio of $7 \cdot 10^{-3}$. Recently R. K. Gupta [4] used scintillation techniques and reported gamma rays of approximately 680, 725 and 1080 keV. He suggested a decay scheme where the two latter are placed to the first excited and ground states respectively, thus defining a third excited state of proposed spin-parity $1(+)$. The 680 keV transition, which could not unambiguously be assigned to Au^{196}, was placed as the above-mentioned crossover. It has been the object of this investigation to study these transitions at good resolution and to assign spin and parity to the new level.

Source preparation

The activity was produced by deuteron irradiation of platinum foils. The strongest source was produced by a 12 h irradiation at the cyclotron of Birmingham with a beam of 20 MeV and approximately 200 μA. As the sources were actually intended for a study of the Au^{194} decay (with a half-life of 40 h) the chemical extraction of the gold phase [5] was usually done only one or two days after the bombardment. Details about the deposition of the activity on to the backings are found in a paper by Bäckström *et al.* [6].

Experimental

The two low-energy transitions were measured in an iron-free spectrometer ($\varrho_0 = 30$, $\beta = \frac{3}{8}$). The source had the dimensions 1×10 mm^2 and was prepared by dipping a strip of mylar coated with a transparent layer of palladium into the acidic solution. The activity plated on to the palladium, giving a very thin source on a backing of thickness 1 mg/cm^2. The source contained, among other activities, Au^{196} and Au^{199}. The lines of the latter isotope had previously been measured "absolutely" with the same instrument [7]. It sufficed therefore to measure the 333 and 356 keV K-lines relative to the 146 keV L_{III} line in Au^{199} to get a precise value for these radiations. The result is[1] $E_1 = 333.03 \pm 0.05$ keV and $E_2 = 355.73 \pm 0.05$ keV.

The lines were measured with a resolution of 0.13 % and no splitting or broadening was observed for the 333 keV line.

An iron yoke double focussing spectrometer ($\varrho = 50$, $\beta = \frac{3}{8}$) was utilized for the rest of the experiment. In the runs for the study of the Au^{194} decay the two most intense lines in Au^{196} were frequently recorded. The ground state transition of the former has, among other methods, been carefully measured relative to X-ray lines by Beckman and Bergvall [9] using a curved crystal spectrometer. By direct comparison we find $E_1 = 333.05 \pm 0.06$ keV and $E_2 = 355.76 \pm 0.08$ keV.

The transition 1080 ± 15 keV, as reported by Gupta, has been found. Actually it lies only ten keV from a well-measured line in Au^{194} making the energy determination simple. The result is 1091.33 ± 0.30 keV. This line definitely belongs to Au^{196}. Gupta followed its decay in sources made by two entirely different methods and found with both a half-life equal to that of Au^{196}. Furthermore, in the three different sources used in this investigation it always appeared with the same intensity relative to other Au^{196} lines.[2] It should be pointed out that there is no contribution in the present measurement from the 1087 keV line of Au^{198}. The line half-width was 0.3 % and the latter line was seen as a small hump at the expected position roughly 8.5 keV further down (see Fig. 1).

A search has been carried out for the reported transitions of 680 ± 20 keV and 725 ± 20 keV. The region corresponding to gamma-ray energies between 650 keV and 756 keV has been thoroughly scanned in internal conversion. With a confidence level of 30 there is in the whole region no line stronger than 1/14 000 of the 356 K-line. By the values established by the decay scheme of Gupta and by the energy values from this work, the upper limits are still smaller. The results are summarized in Table 1.

The sources available were too weak to give, by the method of external conversion, a statistically well-defined γ-intensity for the 1091 keV transition. It was necessary to use high resolution and a thin converter to avoid the 1087 keV Au^{198} gamma. Still it was felt profitable to run the regions corresponding to the quoted

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[1] These values are calculated using a K binding energy for platinum of 78.391 keV and the energy for the mercury X-ray lines $K\alpha_1 = 70.8196 \pm 0.002$ keV and $K\alpha_2 = 68.8952 \pm 0.002$ keV. The two latter values are due to Beckman and Bergvall [8].

[2] These intensity measurements were made in two step processes, using the L-line of the 426 keV transition in Hg^{196} as common member. Its conversion intensity is 1.7 ± 0.1. Using the theoretical conversion coefficients of M. E. Rose the γ-intensity turns out to be 6.7 ± 0.4, (intensity scale of Table 1) and the branching to Hg^{196} (6.2 ± 0.5) %. We find the transition energy 426.13 ± 0.15 keV.

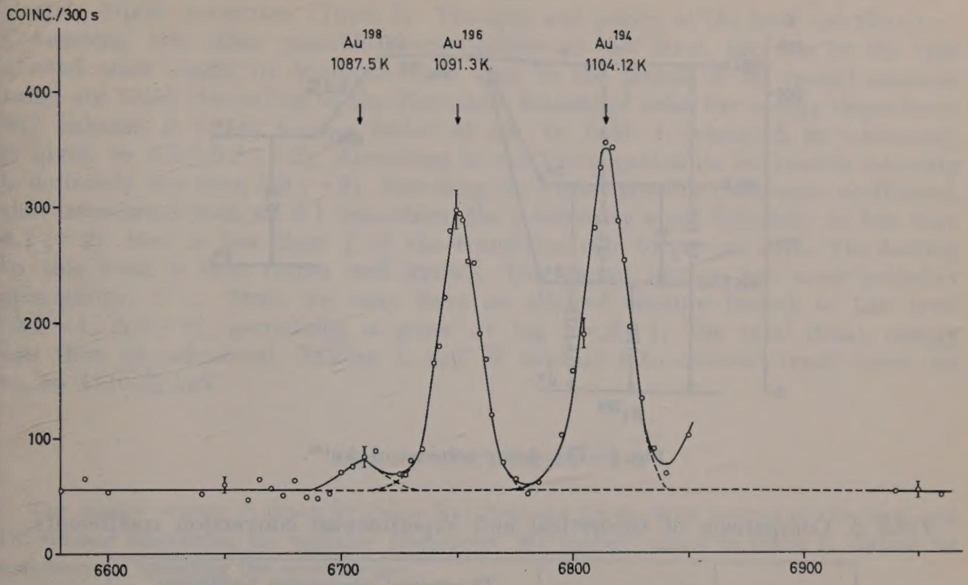

Fig. 1. The K-conversion line of the 1091 keV transition in Au^{196} together with the calibration line in Au^{194}.

Table 1. Summary of energy and intensity measurements.

Energy keV	Gupta	Alburger	This work[a]		
	Rel. photon intensity[b]	Rel. conv. intensity[c]	Energy keV	Rel. conv. intensity	Rel. photon intensity
331	128	37	333.03 ± 0.05	37	28
354			355.73 ± 0.05	100	100
680 ± 20	6.0 ± 3.2 (−2)	< 3.1 (−3)	689 ± 10	< 5.6 (−3)	< 2.2 (−1)
725 ± 20	6.8 ± 3.2 (−2)		735 ± 10	< 3.8 (−3)	< 1.5 (−1)
1080 ± 15	1.92 ± 0.38 (−1)		1091.33 ± 0.30	8.3 ± 0.5 (−3)	1.7 ± 0.4 (−1)

[a] The errors quoted are standard deviations.
[b] Normalized according to column six.
[c] Normalized according to column five.

transitions. For instance, the 1091 keV line counted only 10 counts/300 s on a background of 50 counts/300 s. The γ-intensity given is the result of totally 50 min/point. The γ-intensities have been calculated from the line areas by the method for extended sources of Hultberg [10], taking into account a small correction due to the gamma absorption in the copper that is inserted between source and converter to cut away the beta radiation. This method is accurate to within roughly 5%. The gamma intensities are summarized in Table 1, column six.

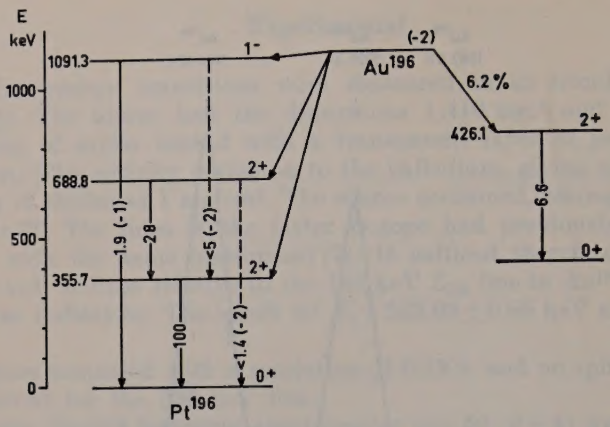

Fig. 2. The decay scheme of Au^{196}.

Table 2. Comparison of theoretical and experimental conversion coefficients.

Transition keV	Experimental conversion coefficient	Theoretical conversion coefficient		
		$E1$	$E2$	$M1$
333	5.3 (−2)		4.8 (−2)	1.27 (−1)
356	Normalized		4.0 (−2)	
1091	1.75 ± 0.36^a (−3)	1.55 (−3)	3.8 (−3)	8.9 (−3)

[a] The γ-intensity of Gupta has been used for this value.

Discussion

Concerning the crossover from the second excited state, our result is that its K-conversion intensity is definitely less than 5.6 (−3); according to Alburger, less than 3.1 (−3).

As this, as well as the 356 keV transition, must be an $E2$ transition, its γ-intensity, calculated from the upper limit of the K-conversion line given by Alburger, must be less than 1.4 (−2). Most probably the γ-intensity (6.0 ± 3.2) (−2) seen by Gupta is a summing line of the two lowest transitions.

From the intensities given in Table 1 some conversion coefficients may be calculated. These are given in Table 2 together with some theoretical coefficients. The conversion coefficient of the 333 keV transition is, keeping in mind that no special experiment was done in order to subtract the compton background under the lines, probably not better than ±10%. Its value agrees with known facts about this transition [11], [12].

The third excited state is defined by the 1091.3 keV transition. No other assignment than to the ground state is possible according to the summing spectra of Gupta. The γ-intensity reported by him is probably more accurate than that measured here. The conversion coefficient decides beyond doubt in favour of an electric dipole transition (Table 2). The spin and parity of the level are thus $1-$. Concerning the other possible de-excitations of this level, the one to the first excited state ought to dominate over that to the second if no special selection rules are valid. According to the Blatt and Weisskopf rules the energy dependence will enhance it by at least a factor of six. In Table 1, column 2, its γ-intensity is given to $6.8 \pm 3.2\ (-2)$. According to our investigation its conversion intensity is definitely less than $3.8\ (-3)$. Assuming the lowest possible conversion coefficient, that associated with an $E\,1$ transition, the γ-intensity must definitely be less than $4.7\ (-2)$; that is less than $\frac{1}{4}$ of the transition rate to ground state. The feeding to this level is thus rather well known. The parent isotope has most probably spin-parity, $2-$. Thus we may have an allowed capture branch to this level ($\Delta I = 1$, $\Delta \pi = 0$), permitting a guess at log $ft = 5 \pm 1$. The total decay energy can then be calculated. Taking L and M capture into account result turns out to be 1110^{+24}_{-11} keV.

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REFERENCES

1. Nuclear Data Sheets NRC 58-1-76. National Research Council, Washington, D.C.
2. Sharff-Goldhaber, G., and Weneser, J., Phys. Rev. *98* (1955) 212.
3. Alburger, D. E., Phys. Rev. *108* (1957) 812.
4. Gupta, R. K., Gamma rays from Au^{196}. Private communication.
5. Wilkinson and Hicks, ed. Meinke, W., Chemical Procedures used in Bombardment Work at Berkeley, UCRL-432.
6. Bäckström, G., Bergman, O., Burde, J., and Lindskog, J., Nuclear Phys. *15* (1960) 570.
7. Bäckström, G., Bergman, O., and Burde, J., Nuclear Phys. *7* (1958) 263.
8. Beckman, O., and Bergvall, P., Phys. Rev. *114* (1959) 1280.
9. Beckman, O., Bergvall, P., and Axelsson, B., Ark. Fys. *14* (1958) 419.
10. Hultberg, S., Ark. Fys. *15* (1959) 307.
11. Thieme, M. T., and Bleuler, E., Phys. Rev. *101* (1956) 1031.
12. Steffen, R. M., Phys. Rev. *89* (1953) 665.

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Uppsala 1960. Almqvist & Wiksells Boktryckeri AB